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EFFECTS OF INFILTRATION AND INFLOW ON WILKESON WASTEWATER TREATMENT PLANT: FINDINGS OF A LIMITED CLASS II INSPECTION AND RECEIVING WATER SURVEY

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ABSTRACT

A limited Class II inspection and receiving water survey were conducted by the Department of Ecology at Wilkeson Wastewater Treatment Plant on March 3 and 4, 1987. Severe infiltration and inflow caused hydraulic overload of treatment processes. Facility retention time was 2.5 days, less than the recommended three-day minimum for an aerated lagoon system. During the inspection, the plant was not in compliance with NPDES permit limits for biochemical oxygen demand (removal efficiency and loads), fecal coliform numbers, or flow. However, effects of wastewater discharge on Wilkeson Creek were minimal due to high stream flows and associated poor water quality. A number of recommendations were made to improve plant performance, foremost of which was correction of the infiltration and inflow problem.

INTRODUCTION

The town of Wilkeson (population 350) is located in north-central Pierce County near Mt. Rainier National Park. Domestic sewage from residential and light commercial sources in town is treated at Wilkeson Wastewater Treatment Plant (WTP), an aerated lagoon system. Treatment is provided by a bar screen, two 90-foot diameter lagoons in series, and chlorination (Figure 1). Both lagoons are vinyl-lined and equipped with a surface aerator. Effluent is discharged to Wilkeson Creek, a Class A tributary of the Puyallup River via South Prairie Creek and the Carbon River. Effluent quality is regulated by NPDES permit #WA-002328-1.

Sanitary sewers in Wilkeson are subject to high infiltration and inflow (I&I) during wet weather. Average sewage flow is estimated to be 0.03 MGD, but I&I can augment flows more than ten-fold, to 0.30 MGD and higher. Design capacity of the WTP is 0.07 MGD. Effects of hydraulic overload on WTP treatment efficiency have not been quantified, but excessive I&I promotes illegal bypasses of raw sewage to Wilkeson Creek from two lift stations. Westech Engineering (1986) studied the municipal sewer system and recommended a number of I&I corrective measures.

The Southwest Regional Office of Ecology requested that the Water Quality Investigations Section (WQIS) conduct a limited Class II inspection and receiving water survey to better define the nature and impact of the I&I problem. A critical consideration was to perform the study at flows exceeding WTP design capacity. Objectives were:

1. Evaluate treatment efficiency and permit compliance at Wilkeson WTP.

2. Assess concomitant effects of WTP discharge on Wilkeson Creek.

3. Characterize the quality of municipal storm sewer effluent.

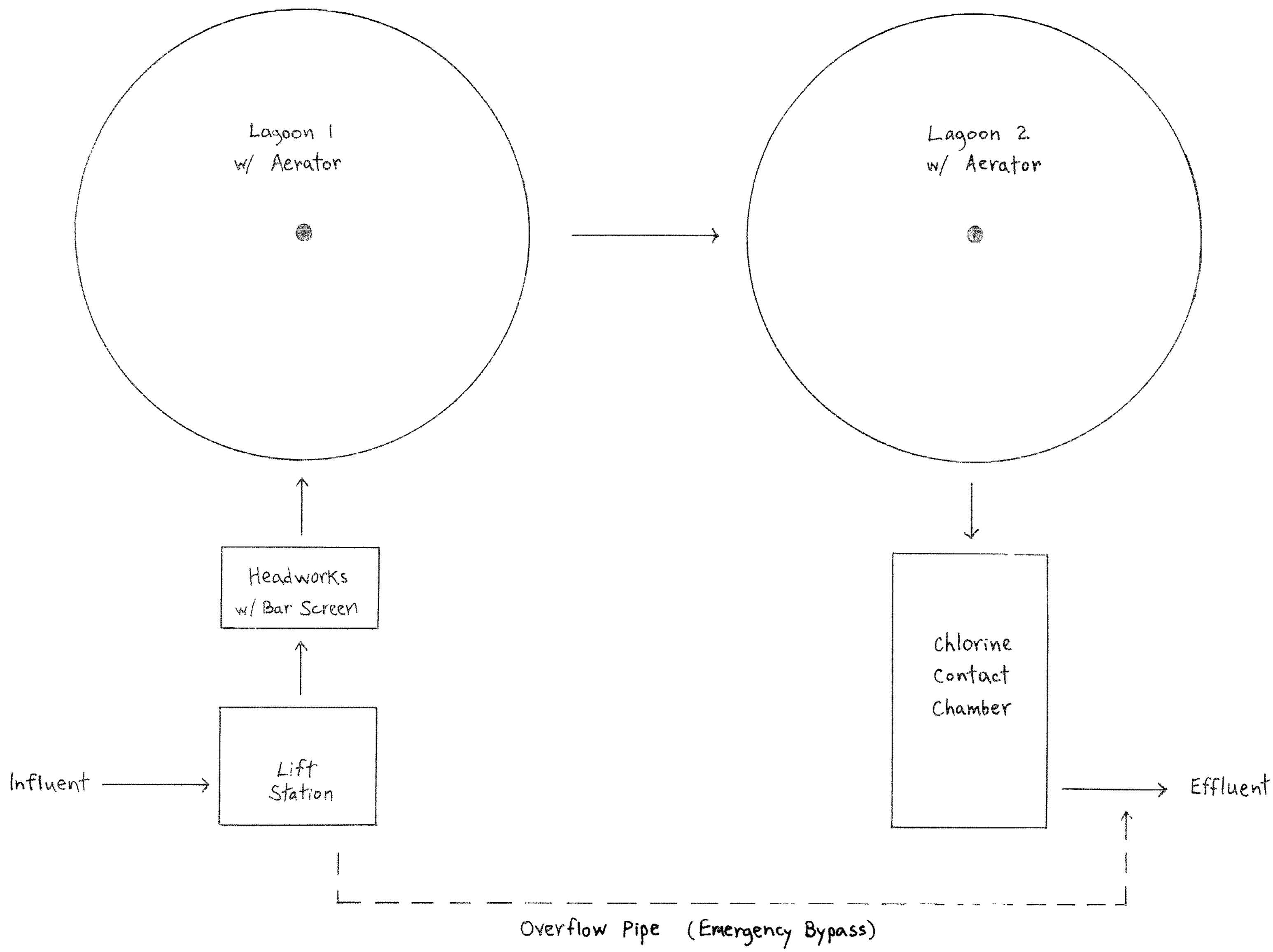

Figure 1. Wastewater flow diagram of Wilkeson WTP.

The limited Class II inspection and receiving water survey were conducted on March 3 and 4, 1987. Field support was provided by Don Reif and Joe Joy of WQIS. Jack Cole, the operator at Wilkeson WTP, assisted with sampling and related aspects of the investigation.

METHODS

Wastewaters influent to the WTP collect in a wet well and are periodically elevated by pump to the headworks. Composite samples were taken from the wet well, while grab samples were taken at the headworks upstream of the bar screen. Grab samples from the lagoons were collected at the surface, about two feet offshore. Composite and grab samples of chlorinated effluent were taken at the 90-degree V-notch effluent weir. Both influent and effluent compositors sampled 200 mL at half-hour intervals over a 24-hour period.

Parameters measured at the WTP were temperature, pH, and specific conductance (Beckman meters); dissolved oxygen (azide-modified Winkler titration); residual chlorine (LaMotte-Palin DPD test); and flow (head height at effluent weir). WTP samples for laboratory analysis were oil and grease, turbidity, solids-4 (total, non-volatile total, suspended, and non-volatile suspended), nutrients-3 (nitrate-nitrite, ammonia, and total phosphorus), 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and fecal coliform (FC) bacteria. Sludge and wastewater depths in the lagoons were measured from a rowboat using a Sludge Judge.

Receiving water quality was sampled at six sites on each day (Figure 2). The station at river mile (r.m.) 5.0 served as an upstream control. Station 4.6 was immediately upstream of a storm sewer outfall and a sewage lift station emergency bypass. (The emergency bypass for the other lift station, located at the WTP, connects to the effluent outfall line.) Station 4.0 was downstream of all stormwater inflows but upstream of the WTP discharge; thus, it served as the control site for WTP effects.

Sampling proceeded in an upstream direction, with surface samples being taken several feet offshore. In addition, three major storm sewer outfalls were sampled the first day. Parameters measured in the field were temperature, pH, conductivity, dissolved oxygen, and residual chlorine (methods described earlier). Due to high water, stream discharge was measured only once (Marsh-McBirney current meter). Storm sewer flows were estimated using a bucket and stopwatch. Samples for laboratory analysis were turbidity, total suspended solids (TSS), nutrients-3, and FC.

Samples collected during the limited Class II inspection and receiving water survey were iced and shipped within 24 hours to Ecology's laboratory in Manchester, Washington. Samples were processed and analyzed in accordance with EPA (1979) and APHA, et al. (1985).

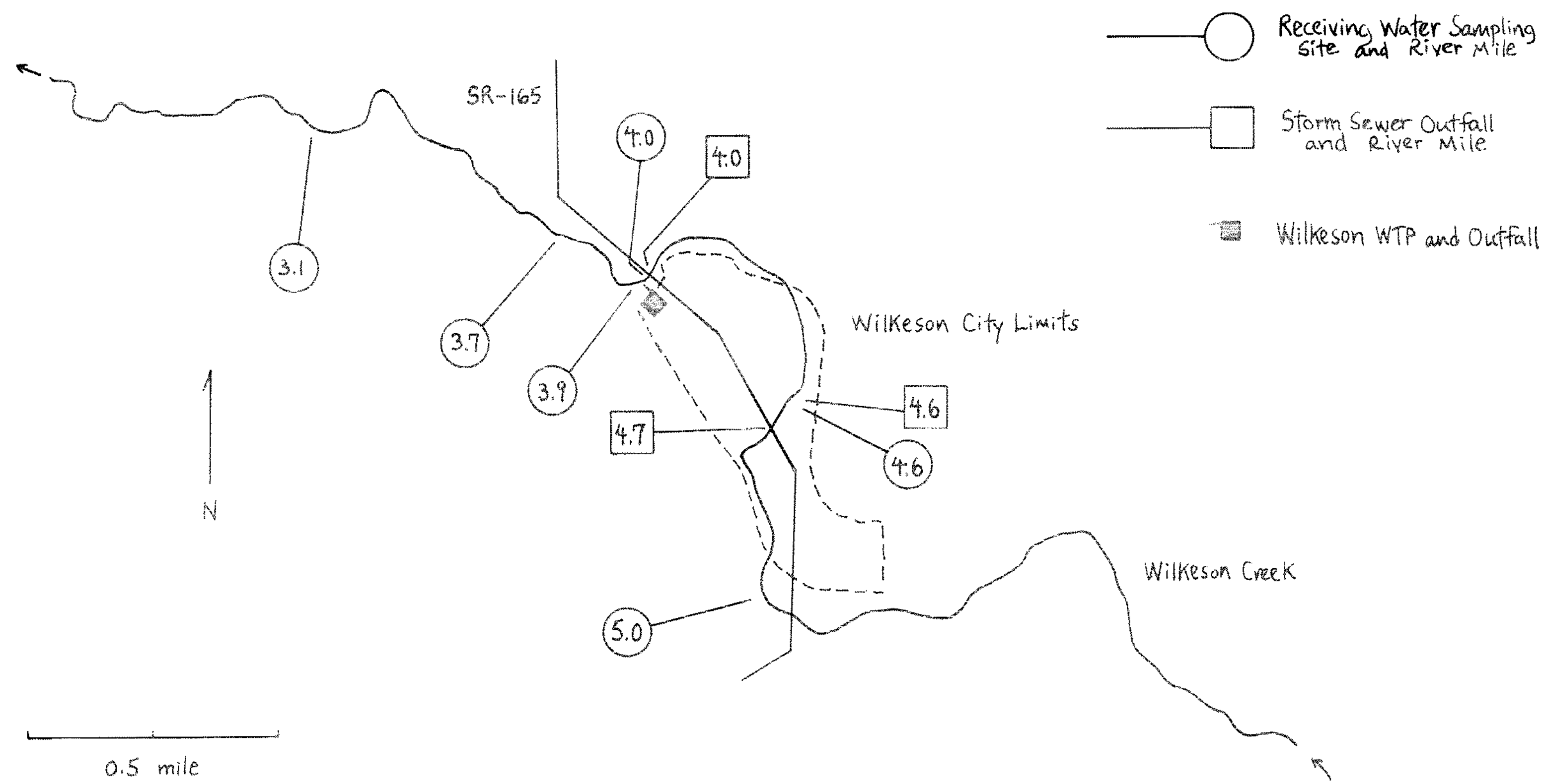

Figure 2. Map of Wilkeson Creek showing location of Wilkeson WTP outfall and receiving water sampling sites.

RESULTS AND DISCUSSION

Limited Class II Inspection

Flows at Wilkeson WTP exceeded the design capacity of the facility for the duration of the inspection (Figure 3). The immediate system response to I&I was evidenced by the close correlation of daily rainfall and WTP discharge values. Measurements of head height over the effluent weir indicated the WTP flow meter overestimated discharge by about 0.03 MGD, in the range 0.10 to 0.20 MGD (Table 1). This trend apparently continues at higher flows: the meter has periodically peaked out at 0.36 MGD, but the maximum pumping capacity of the WTP lift station is only 0.33 MGD. The meter should be checked and recalibrated to improve the accuracy of WTP flow monitoring. If lift station pump capacity is increased in the future, the meter should be adjusted (if possible) or replaced to enable measurement of flows exceeding 0.36 MGD.

Wastewaters influent to Wilkeson WTP were weaker than the effluent, indicating severe hydraulic overload of treatment processes (Table 2). The large volume of I&I diluted raw wastes considerably and caused premature discharge of lagoon contents. Effluent waste strength was higher than influent for conductivity, total solids, ammonia, total phosphorus, and BOD_5. Weekly influent samples collected by the operator in February 1987 had mean TSS and BOD_5 concentrations of 160 and 130 mg/L, respectively, compared to 55 and <20 mg/L on March 3 and 4.

Lagoon and effluent dissolved oxygen levels dropped about 2 mg/L during the course of the inspection, even though aeration frequency increased. Oxygen decreases in lagoon 2 and WTP effluent were expected because high flows accelerated passage of less-treated (i.e., higher oxygen-demanding) wastewater from lagoon 1 to 2 and lagoon 2 to effluent. The oxygen decline in lagoon 1, while of lesser magnitude than in lagoon 2 or effluent, was nonetheless unexpected.

The operator was uncertain if aeration frequency in the lagoons was adequate and requested guidance on the subject. The aerator in lagoon 1 was run 8.1 hours on March 3 and 10.2 hours on March 4. The aerator in lagoon 2 was operated 1.3 hours both days. Optimal aeration frequency may vary from day to day, but as a general rule the aerators should be operated so as to maintain at least 2 mg/L dissolved oxygen in both lagoons (EPA, 1983). Aeration practices at Wilkeson WTP met this criterion.

Effluent FC levels were high, possibly due to several factors. FC die-off prior to disinfection is largely a function of hydraulic retention time; densities of 200 per 100 mL can be achieved without disinfection if sufficient detention is provided (Middlebrooks et al., 1982). By lessening retention time, I&I may have reduced natural die-off rates and thus increased the number of bacteria to be killed in chlorination. Concurrently, I&I would have reduced detention in the chlorine contact chamber, leading to less efficient disinfection. Hence despite adequate chlorine residuals, hydraulic retention at

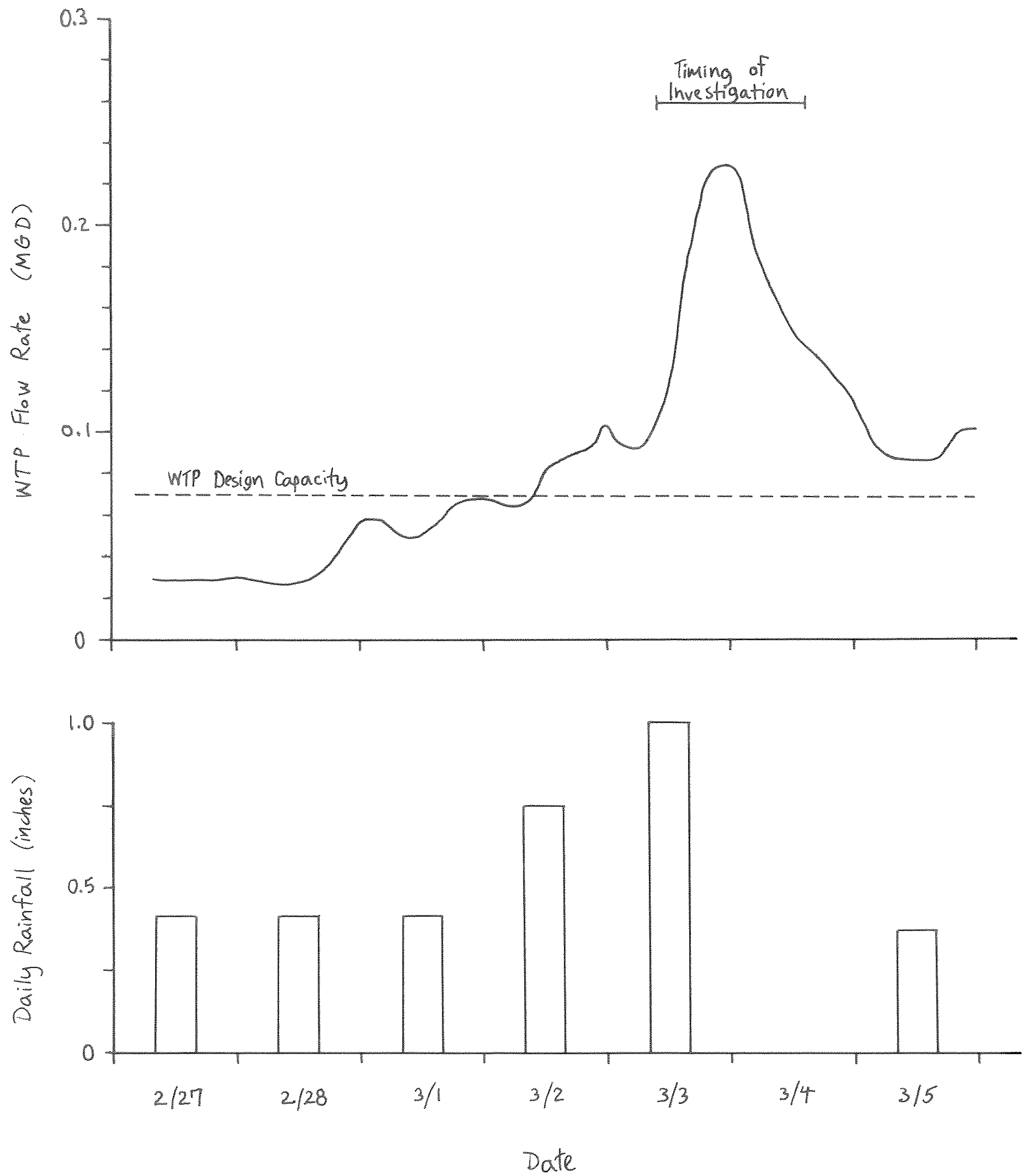

Figure 3. Effluent flow rates and daily rainfall at Wilkeson WTP during the week of February 27 to March 5, 1987 (daily rainfall values for 2/27 to 3/1 represent the average rainfall over the 3-day interval; no measurable rainfall occurred on 3/4).

Table 1. Comparison of instantaneous flows measured at Wilkeson WTP by the operator (Badger flow meter) and Ecology (head height at effluent weir), March 1987.

		Instantaneous Flow (MGD)	
Date	Time	Operator	Ecology
March 3	1025	0.11	0.10
	1325	0.14	0.13
	1630	0.20	0.16
March 4	1010	0.16	0.12
	1325	0.14	0.11
	Average	0.15	0.12

Table 2. Wastewater quality measured during a limited Class II inspection at Wilkeson WTP on March 3 and 4, 1987.

			Field							Laboratory											
							Dissolved Oxygen					Solids (mg/L)**				Nutrients (mg/L)					
Site	Date	Time	Flow (MGD)*	Temp. (^oC)	pH (S.U.)	Cond. (umhos/cm)	mg/L	% Sat.	Res. Chl. (mg/L)	Oil & Grease (mg/L)	Turb. (NTU)	TS	TNVS	TSS	TNVSS	NO_3-N/ NO_2-N	NH_3-N	Total P	BOD_5 (mg/L)	COD (mg/L)	Fecal Coliform (#/100 mL)
Influent	3/3	1015	--	9.7	7.1	230	--	--	--	13	--	--	--	--	--	--	--	--	--	--	--
		1320	--	9.4	7.0	180	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	3/4	0945	--	9.8	7.9	330	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1325	--	9.7	7.0	300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Comp.+	--	3.1	7.0	205	--	--	--	--	9	190	100	55	10	1.2	3.8	0.71	<20	150	--
Lagoon 1	3/3	1045	--	8.8	7.4	410	6.60	58	--	--	--	--	--	--	--	--	--	--	--	--	--
		1330	--	9.2	7.4	390	6.40	57	--	--	--	--	--	--	--	--	--	--	--	--	--
	3/4	0950	--	9.6	7.1	305	5.60	50	--	--	--	--	--	--	--	--	--	--	--	--	--
		1335	--	10.0	7.2	310	5.10	46	--	--	--	--	--	--	--	--	--	--	--	--	--
Lagoon 2	3/3	1040	--	7.6	7.5	495	6.60	57	--	--	--	--	--	--	--	--	--	--	--	--	--
		1335	--	8.2	7.6	480	7.60	66	--	--	--	--	--	--	--	--	--	--	--	--	--
	3/4	0950	--	8.8	7.3	410	5.65	50	--	--	--	--	--	--	--	--	--	--	--	--	--
		1335	--	9.4	7.3	445	4.40	39	--	--	--	--	--	--	--	--	--	--	--	--	--
Effluent	3/3	1025	0.10	7.8	7.3	490	6.00	52	0.6	2	--	--	--	--	--	--	--	--	--	--	1400
		1325	0.13	7.7	7.4	490	6.25	54	0.4	--	11	--	--	32	--	0.20	16	0.94	--	--	2400
	3/4	1010	0.12	8.7	7.1	400	3.95	35	0.5	--	--	--	--	--	--	--	--	--	--	--	2600
		1325	0.11	8.8	7.2	435	4.15	37	0.4	--	8	--	--	27	--	0.33	12	2.2	--	--	1400
		Comp.+	0.19	3.1	7.4	450	--	--	--	--	9	300	150	28	7	0.24	28	2.5	24	110	--

* = From head height measurements; final value (Time = Comp.) from WTP flow totalizer.

** = TS = total solids; TNVS = total non-volatile solids; TSS = total suspended solids; TNVSS = total non-volatile suspended solids.

\+ = 24-hour composite samples: 1015 on March 3 to 1015 on March 4.

Wilkeson WTP may have been insufficient to effect satisfactory reductions in FC numbers.

Chlorination efficiency is also reduced by poor initial mixing and short-circuiting in the contact basin. The chlorine injection system at Wilkeson WTP appeared to be deficient and should be replaced with an in-line mixer or multi-port injector. Repositioning of baffles may further improve hydraulic performance of the contact tank. Although chlorination was not flow-proportioned, effluent residuals indicated chlorine dosing was adequate.

Presence of solids in Wilkeson WTP effluent may have interfered with chlorination efficiency as well. Solids exert a chlorine demand, thus their accumulation in the contact basin should be prevented. Reduced sludge build-up would also increase detention time and discourage short-circuiting.

Effluent from Wilkeson WTP failed to comply with several NPDES permit limitations during the inspection (Table 3). Removal of BOD was negligible due to dilution of influent wastes with I&I and treatment failure owing to hydraulic overload. BOD loading exceeded both weekly and monthly average permit limits, while TSS loading matched the monthly limit. FC limitations were also violated. The monthly average flow limit of 0.07 MGD was exceeded throughout the inspection.

The maximum depth of both lagoons was estimated to be 10 feet (Figure 4). Sludge depth was greater in lagoon 1 than lagoon 2. Sludge build-up near the center of both lagoons was minimal due to aerator erosion. Solids deposition within each lagoon appeared uneven, creating increased potential for short-circuiting. The observed pattern of sludge accumulation may be an artifact of historical WTP operation. The present operator aerates much more frequently, enough so that uniform mixing and deposition of solids would be expected.

The original volume of Wilkeson WTP exceeded 570,000 gallons, but sludge accumulation has reduced treatment capacity by 16 percent (Table 4). The reciprocal relationship between WTP flow (F) in MGD and hydraulic retention time (HRT) in days was calculated as:

$$HRT = 0.49/F$$

Design criteria for aerated lagoon systems specify a minimum detention time of 3 days (Hinrichs, 1979; Middlebrooks et al., 1982). During the inspection, mean treatment time was 2.5 days. Retention during severe I&I events (0.33 MGD) drops to 1.5 days. Westech Engineering (1986) recommended I&I be reduced so that peak flows do not exceed 0.15 MGD, claiming that treatment should be satisfactory below such flows. Using the above equation, retention at 0.15 MGD would be 3.3 days, slightly more than the minimum requirement.

Chlorine contact time should exceed 20 minutes at peak flows (Ecology, 1985). Hydraulic retention in the contact basin at Wilkeson WTP was about 17 minutes during our investigation, and is estimated to be 10

Table 3. Assessment of NPDES permit compliance during a limited Class II inspection at Wilkeson WTP on March 3 and 4, 1987.

Parameter	Units	NPDES Permit Limit Monthly Average	NPDES Permit Limit Weekly Average	Grab[a]	Composite
BOD_5	mg/L	30[b]	45	--	24
	lbs/day	18	26	--	38[c]
	% removal	85	--	--	0
TSS	mg/L	75	110	--	28
	lbs/day	44	64	--	44[c]
	% removal	--	--	--	49
Flow	MGD	0.07	--	--	0.19[d]
Fecal Coliform	#/100 mL	200	400	1,870	--
pH	S.U.	$6.0 \leq pH \leq 9.0$		7.2	--
Total Residual Chlorine	mg/L	Minimum required to meet fecal limit		0.5	--

[a]Mean values.

[b]Limit is 30 mg/L or 85 percent removal, whichever is more stringent.

[c]Calculated as 8.34 x 0.19 MGD x concentration in mg/L.

[d]WTP totalizer reading (24 hours).

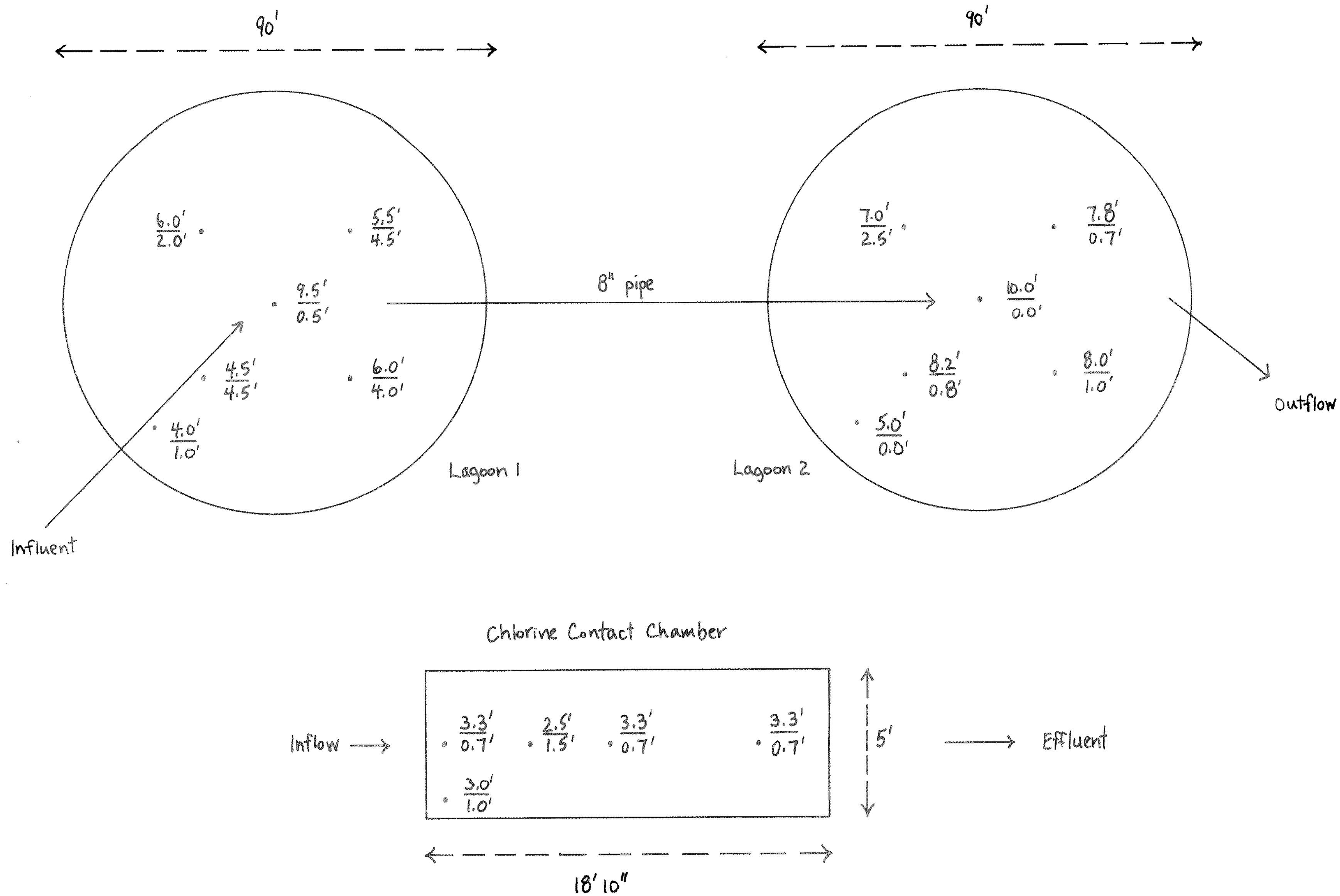

Figure 4. Water (upper numeral) and sludge (lower numeral) depths in the aerated lagoons and chlorine contact chamber of Wilkeson WTP, March 1987.

Table 4. Volume and hydraulic retention time of treatment units at Wilkeson WTP, March 1987.

Parameter	Treatment Units			
	Lagoon 1	Lagoon 2	CCC[a]	Total
Volume (gallons)[b]				
Total	285,000	285,000	2,800	573,000
Wastewater	231,000	249,000	2,200	482,000
Sludge	54,000	36,000	600	91,000
Hydraulic Retention Time[c]				
At Sewage Flows (0.025 MGD)	9.2 d	10.0 d	127 m	19.3 d
At Design Flows (0.070 MGD)	3.3 d	3.6 d	45 m	6.9 d
At Survey Flows (0.19 MGD)	1.2 d	1.3 d	17 m	2.5 d
At Peak Flows (0.33 MGD)	0.7 d	0.8 d	10 m	1.5 d

[a]Chlorine contact chamber.

[b]Total lagoon volume from Wilkeson WTP Operation and Maintenance Manual; lagoon wastewater volumes calculated using truncated cone formulation; CCC volumes calculated as length x width x depth.

[c]Based on existing wastewater volumes, not original (total) volumes; d = days; m = minutes.

minutes at peak flows. As discussed earlier, reduced contact time decreases the efficiency of disinfection and thus inadequate detention may largely account for the high effluent FC levels observed during the inspection.

The grounds and facilities at Wilkeson WTP were well maintained and the operator was enthusiastic in performing his duties. The bar screen appeared to be homemade and somewhat ineffective; repair or replacement is warranted. The operator reported that erosion of inner dike walls was a by-product of weed cutting. As a remedy, he was considering using a goat for weed control. However, if grazing by a hoofed animal furthers bank wear, the operator should consider stabilization by sowing dike walls with a grass that forms better sod.

During a verbal review of permit compliance monitoring activities, the operator disclosed a defect in sampling procedure, namely the failure to dechlorinate FC samples. Consequently, disinfection continues for many hours prior to analysis, biasing results downward. Also, FCs were tested from a composite sample instead of a grab sample. The operator was advised of correct sampling procedure and has remedied both problems.

Receiving Water Survey

The WTP discharges effluent into Wilkeson Creek at r.m. 3.9, just downstream of the SR-165 bridge (Figure 2). The outfall is an eight-inch concrete pipe which emerges from the left bank and is exposed during low to moderate stream flows. As a sanitary and aesthetic measure, the line should be extended so as to submerse the outfall.

The effect of WTP discharge on the receiving environment was difficult to discern in light of high stream flows and associated poor water quality (Table 5). The receiving-water-to-effluent dilution ratio exceeded 800:1, and WTP discharge caused no violation of state water quality standards.

Comparison of stations 4.0 and 3.9/3.7 revealed that several parameters increased slightly downstream of the outfall. However, sampling and analytical variability could easily explain the differences. Ammonia increased considerably below the outfall, but concentrations continued to rise farther downstream. As the creek was bordered by pasture in this reach, the source of ammonia was believed to be primarily nonpoint. The chronic toxicity threshold for un-ionized ammonia at ambient temperatures and pHs would occur at total ammonia levels exceeding 0.95 mg/L.

Wilkeson Creek was turbid throughout the study reach, more so on March 3 than March 4 (rainfall was heavy the first day but negligible the second). A brief upstream reconnaissance showed the watershed was heavily clear-cut, hence the degradation in water quality may have been largely man-caused. Suspended solids concentrations on day 1 decreased steadily and markedly from r.m. 5.0 to 3.1, indicating substantial deposition of solids occurred in this reach.

Table 5. Water quality in Wilkeson Creek upstream and downstream of Wilkeson WTP outfall, March 3 and 4, 1987.

					Field							Laboratory					
									Dissolved Oxygen								
Sampling Site	River Mile	River Bank[a]	Date	Time	Flow (cfs)	Temp. (^oC)	pH (S.U.)	Cond. (umhos/cm)	mg/L	% Sat.	Res. Chl. (mg/L)	Turb. (NTU)	TSS (mg/L)	NO_3-N/NO_2-N (mg/L)	NH_3-N (mg/L)	Total-P (mg/L)	Fecal Coliform (#/100 mL)
Wilkeson Creek																	
Above town at city watershed	5.0	R	3/3	1610	--	6.5	7.4	60	11.75	98	--	19	78	0.63	0.03	0.10	11
			3/4	1450	--	7.7	7.5	48	11.30	97	--	6	20	0.71	0.03	0.03	1
Within town at end of Rousher Street	4.6	R	3/3	1535	--	6.6	7.3	68	11.60	97	--	17	73	0.76	0.04	0.09	66
			3/4	1440	--	8.1	7.5	50	11.35	99	--	6	23	0.57	0.04	0.03	1
Below town, 20 yds above WTP outfall	4.0	L	3/3	1445	--	7.1	7.2	51	11.55	98	--	17	69	2.0	0.06	0.09	26
			3/4	1430	--	7.8	7.5	51	11.30	97	--	7	24	0.46	0.04	0.03	1
WTP effluent	3.9	L	3/3	1325	0.20	7.7	7.4	490	6.25	54	0.4	11	32	0.20	16	0.94	2,400
			3/4	1325	0.17	8.8	7.2	435	4.15	37	0.4	8	27	0.33	12	2.2	1,400
20 yds below WTP outfall	3.9	L	3/3	1415	--	7.4	7.2	55	11.50	98	<0.1	15	59	0.42	0.15	0.13	37
			3/4	1420	--	8.4	7.8	52	11.30	99	<0.1	7	24	0.47	0.21	0.07	5
400 yds below WTP outfall	3.7	R	3/3	1400	--	7.7	7.3	55	11.55	99	--	14	61	0.52	0.14	0.08	37
			3/4	1400	--	8.7	8.1	63	11.35	100	--	7	22	0.38	0.30	0.05	6
Johns Road crossing	3.1	R	3/3	1305	--	7.1	7.6	50	11.60	98	--	10	41	0.63	0.37	0.07	31
			3/4	1245	244	8.1	7.5	48	11.35	98	--	8	26	0.47	0.45	0.04	7
Storm Sewer Outfalls																	
SR-165 crossing in town	4.7	R	3/3	1600	0.12	8.4	7.5	145	--	--	--	35	69	0.92	0.03	0.20	20,000
End of Rousher St.	4.6	R	3/3	1530	0.06	10.0	7.4	21	--	--	--	55	910	0.06	0.02	1.4	730
SR-165 crossing NE of town	4.0	L	3/3	1450	0.19	9.7	6.4	48	---	--	--	27	100	0.17	0.03	0.23	520

[a]Facing downstream, sampling occurred several feet off-shore the left (L) or right (R) bank.

Storm sewer discharges had variable characteristics but all were of poor quality. The stormwater outfall at r.m. 4.7 had a high FC concentration, suggesting the presence of illegal sanitary waste discharge(s). The outfall at r.m. 4.6 had very high turbidity and suspended solids, but conductivity was inexplicably low. Storm sewer effluent at r.m. 4.0 had a surface oil sheen. Comparison of receiving water sites 5.0 and 4.6/4.0 showed the sole cumulative impact of stormwater discharge on the creek to be an increase in FC numbers. No lift station bypasses of raw sewage occurred during the survey (high-water alarms were not tripped).

Suspended solids loads in Wilkeson Creek were higher than wastewater and stormwater solids loads by several orders of magnitude (Table 6). Instream loads of nitrate-nitrite and total phosphorus were also substantially higher than other sources. WTP effluent ammonia loads were comparable to upstream ammonia loads, but were insufficient to account for the load increase observed between r.m. 4.0 and 3.9. Again, this and subsequent ammonia load increases were attributed to nonpoint source inputs. Instream FC loads were principally a function of wastewater and stormwater bacterial loads.

CONCLUSIONS AND RECOMMENDATIONS

- Wilkeson WTP is generally well run, but subject to hydraulic overload under wet weather conditions due to a severe I&I problem. During a limited Class II inspection, flows exceeded WTP design capacity, resulting in incomplete waste treatment. Facility retention time was 2.5 days, less than the recommended 3-day minimum for aerated lagoon systems. Several NPDES permit limits were violated, including BOD removal efficiency (zero percent), BOD loading (38 lbs/day), and FC numbers (1,870 per 100 mL).

- I&I corrective measures should be implemented as soon as possible to prevent recurrence of treatment failures. As part of the rehabilitation project, lift station bypasses of raw sewage should be eliminated. Also, the storm sewer located at r.m. 4.7 should be inspected for the presence of illegal sanitary waste discharge(s).

- A number of suggestions were offered to improve plant operations, including repair or replacement of the bar screen, upgrade of the chlorine injection system, and recalibration of the WTP flow meter. The outfall line should be submersed for sanitary and aesthetic purposes.

- Due to the severity of the I&I problem, weekly monitoring of influent and effluent wastewater quality should continue. Weekly monitoring will also provide the operator rapid feedback concerning aeration and chlorination adequacy. Defects in FC sampling procedure were identified and corrected.

Table 6. Suspended solid, nutrient, and bacterial loads of WTP effluent, municipal storm sewers, and Wilkeson Creek on March 3 and 4, 1987.

Site	River Mile	Loads[a] TSS (lbs/day)	NO_3-N/ NO_2-N (lbs/day)	NH_3-N (lbs/day)	Total-P (lbs/day)	Fecal Coliform (no. x 10^3/sec)
WTP Effluent[b]	3.9	44	0.38	44	3.9	150
Storm Sewer Outfalls[c]						
SR-165 crossing in town	4.7	45	0.60	0.02	0.13	680
End of Rousher Street	4.6	290	0.02	<0.01	0.45	12
SR-165 crossing NE of town	4.0	100	0.17	0.03	0.24	28
Sum		435	0.79	<0.06	0.82	720
Wilkeson Creek[d]						
Above town at city watershed	5.0	64,000	880	39	85	200
End of Rousher Street, above storm drain	4.6	63,000	870	53	79	600
20 yards above WTP outfall, below storm drain	4.0	61,000	1,600	66	79	400
20 yards below WTP outfall	3.9	55,000	590	240	130	900
400 yards below WTP outfall	3.7	55,000	590	290	85	1,000
Johns Road crossing	3.1	44,000	720	540	72	1,000

[a] Flow in cfs x concentration in mg/L x 5.39 = load in lbs/day;
Flow in cfs x fecal coliform per 100 mL x 284.7 = load in number/second.

[b] Calculated using 0.29 cfs (0.19 MGD), compositor data for TSS and nutrients, and geometric mean of four grabs for fecal coliform.

[c] Based on a single day of sampling.

[d] Calculated for all sites using 2-day means at 244 cfs.

- Impacts of WTP discharge on Wilkeson Creek were minimal due to high stream flows and associated poor water quality. The combined effect of wastewater and stormwater discharges to the creek was a slight elevation of FC numbers, but no violations of state water quality standards occurred.

REFERENCES

APHA, et al. (American Public Health Association, American Water Works Association, and Water Pollution Control Federation), 1985. Standard Methods for the Examination of Water and Wastewater. 16th ed. Washington D.C. 1268 pp.

Ecology (Washington State Department of), 1985. Criteria for Sewage Works Design. Ecology report 78-5, Olympia, WA. 276 pp.

EPA (United States Environmental Protection Agency), 1979. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020. Cincinnati, OH. 460 pp.

EPA, 1983. Design Manual: Municipal Wastewater Stabilization Ponds. EPA-625/1-83-015. Cincinnati, OH. 327 pp.

Hinrichs, D.J., 1979. Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants. EPA/430/9-79-010. Washington D.C. 348+ pp.

Middlebrooks, E.J., C.H. Middlebrooks, J.H. Reynolds, G.Z. Walters, S.C. Reed, and D.B. George, 1982. Wastewater Stabilization Lagoon Design, Performance and Upgrading. MacMillan Publ. Co., New York, NY. 356 pp.

Westech Engineering Inc., 1986. Town of Wilkeson, Washington: Evaluation of Municipal Sewers, March 1986. Salem, OR. 49+ pp.